CHAPTER 1

PLANNED MAINTENANCE SYSTEM AND FAULT ISOLATION

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Describe the purpose of maintenance systems.

2. Describe the methods used in identifying system faults.

INTRODUCTION

The increasing complexity of our equipments requires a viable maintenance program to ensure that the systems perform in a manner that will ensure maximum operational readiness. To overcome this problem, the Navy has developed an excellent preventive maintenance system—the Ships' Maintenance and Material Management (3-M) System. This system provides a standard means for planning, scheduling, controlling, and performing planned maintenance on all equipment.

It is not uncommon for a Fire Controlman Second Class to be in the position of a work-center supervisor. As such, you will need a broader knowledge of a variety of subjects to perform your duties in a professional manner. One area you cannot take lightly is maintenance. Your fire-control system is kept at its maximum level of readiness through maintenance. To help you in this area, this chapter briefly discusses the Planned Maintenance System (PMS) and fault-isolation procedures.

The information provided in this chapter is not intended to cover all aspects of the 3-M System. For more in-depth information on this system, refer to the *Ships' Maintenance and Material Management (3-M) Manual,* OPNAVINST 4790.4.

PLANNED MAINTENANCE SYSTEM

The Planned Maintenance System (PMS) provides a standard means for planning, scheduling, controlling, and performing planned maintenance to complex mechanical, electrical, and electronic equipments. PMS maintenance actions are the minimum required to maintain equipment in a fully operable condition and within specifications. The PMS includes a Maintenance Data System (MDS), which is used to record important scheduled and corrective maintenance information, and electronic data-processing capabilities, which are used to retrieve this information for maintenance analysis. The *3-M Manual* establishes the PMS and assigns PMS management responsibilities.

The PMS provides regularly scheduled tests to detect degraded performance and to aid in preventing failures during tactical operations. When failures do occur, the PMS provides formal corrective maintenance in step-by-step fault-isolation and repair procedures. Complete technical documentation (including combat systems, subsystems, and individual equipment manuals) is an integral part of the PMS. These manuals provide the necessary information for understanding, operating, and maintaining combat systems.

Shipboard maintenance falls into three categories: (1) maintenance within the capability of ship personnel (organizational level); (2) maintenance requiring assistance from outside the ship (intermediate level), such as tender or fleet technical support centers; and (3) maintenance requiring port facilities (depot level), such as shipyard maintenance. Since the objective of the PMS is to perform maintenance at the organizational or intermediate level, it does not reflect depot-level maintenance. Combat systems readiness requires efficient maintenance. The key to this capability is an organized system of planned maintenance that is designed to ensure the maximum operational readiness of the combat systems.

This section describes the PMS objective, the maintenance scheduling and data system, and the integrated maintenance.

PMS OBJECTIVE

The PMS objective is to maximize operational efficiency of all equipment and to reduce downtime, maintenance man-hours, and maintenance costs. Although the PMS provides methods and resources to accomplish each objective, it is not self-sufficient and does not replace the initiative of maintenance supervisors nor does it reduce the necessity for technically competent personnel. Recording and providing feedback of maintenance and personnel data allow continuing management analysis for the improvement of maintenance methods and personnel management. Full use of the planning methods, along with the acceptance and cooperation of technicians, supervisors, and management personnel, produces a maintenance system with the inherent confidence, reliability, and capability to help achieve maximum combat systems readiness.

A sampling of data gathered from the fleet shows conclusively that those ships that adhere to their PMS schedules maintain a significantly higher state of material readiness with no greater maintenance manpower usage than those ships that do not adhere to their PMS schedules.

The primary ingredients of the PMS program are

1. comprehensive procedures for planned maintenance of the combat systems, subsystems, and equipment;

2. system fault-isolation procedures;

3. maintenance task performance scheduling and control; and

4. methods, materials, tools descriptions, and personnel required for maintenance.

Adherence to the PMS program will produce

1. improved confidence in system maintenance,

2. reduced testing time,

3. elimination of redundant testing resulting from uncoordinated testing, and

4. detection of most malfunctions during scheduled maintenance events.

MAINTENANCE SCHEDULING

The normal flow of events that maintenance managers use in developing an integrated maintenance schedule is shown in figure 1-1. This figure shows maintenance management responsibilities and the sequence of events that flow from the department master and work-center PMS record books through the scheduling aids to test execution, unscheduled maintenance, and reporting.

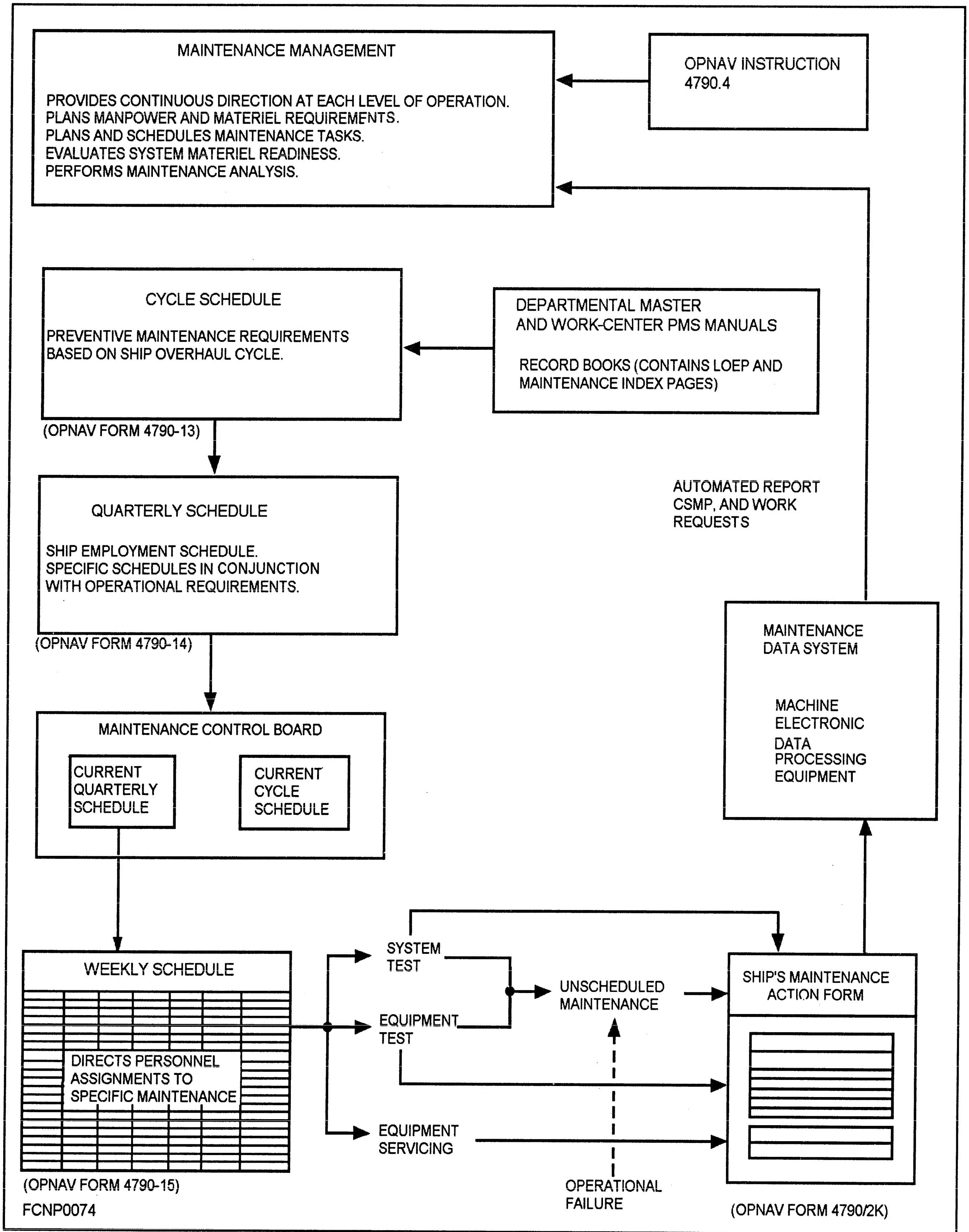

Figure 1-1.—Block diagram of the Planned Maintenance System.

The maintenance control board contains the cycle schedule and the current and subsequent quarterly schedules. The board summarizes the status of current and planned combat systems preventive maintenance. It is updated weekly by the division officer for all deferred and completed maintenance items.

This subsection describes the maintenance index page and the cycle, quarterly, and weekly schedules.

Maintenance Index Page

The maintenance index page (MIP) contains a brief description of the requirements on the maintenance requirement card for each item of equipment, including the periodicity code, the man-hours involved, the minimum required skill level, and, if applicable, the related maintenance requirements. The MIPs for all equipments in a department are maintained in the department's master PMS record, the record that is used by the department head to schedule maintenance on the PMS schedule forms. Each work center has a work-center PMS record that contains the MIPs applicable to that work center.

Cycle Schedule

The cycle schedule is a visual display of preventive maintenance requirements based on the ship's current overhaul cycle. It is used by department heads to assist in the quarterly planning of non-PMS-related activities, such as inspections and training.

Quarterly Schedule

The quarterly schedule, planned from the cycle schedule, is a visual display of the ship's employment schedule. It is prepared by department heads in cooperation with division officers and maintenance group supervisors. The schedule shows the current status of preventive maintenance for each group and assigns specific requirements in conjunction with the ship's operational schedule.

Weekly Schedule

The weekly schedule is a visual display that is normally posted in the working area of each maintenance group. The maintenance group supervisor uses the weekly schedule to assign specific personnel to perform maintenance on specific equipment. Assignments include system and equipment tests and service procedures.

MAINTENANCE DATA SYSTEM

The Maintenance Data System (MDS) has three functions. It provides a means of (1) recording maintenance actions, (2) processing the recorded data to define important facts about maintenance and equipment, and (3) retrieving information for analysis. Significant data identified by the system include the reason the malfunction occurred and the manner in which it was discovered, the man-hours expended, the exact equipment affected, any delays in repair, the reasons for delays, and the types of maintenance personnel required.

Recording Maintenance Actions

Maintenance personnel should record (document) certain shipboard maintenance actions and corrective maintenance on specific categories of equipment at the time the maintenance actions are performed or deferred. Information is recorded and submitted to the MDS for input on the Ship's Maintenance Action Form (OPNAV 4790/2K).

Processing Recorded Data and Analyzing Information

The MDS data-processing facilities collect, store, and analyze maintenance information inputs into the system. The MDS yields a data path concerning equipment maintainability and reliability, man-hour usage, equipment alteration status, material usage and costs, and fleet material condition. Various automated reports are produced periodically for ships, repair activities, unit commanders, and type commanders. These automated reports include current ship's maintenance project files, work requests, and preinspection and survey deficiency listings.

INTEGRATED MAINTENANCE

Combat systems maintenance is based on a concept of performing a comprehensive schedule of tests at three mutually supporting levels: (1) combat systems, (2) subsystems, and (3) equipment. These integrated tests are structured to challenge all combat systems fictions, parameters, and characteristics on a scheduled periodicity against specified tolerances. Successful performance of the tests as scheduled should provide a high level of confidence in the functional operability of the combat systems equipment.

Integrated maintenance requirements are established through engineering analysis based on the study of all factors having a significant effect on maintenance. The analysis defines system and equipment functions and establishes tolerances in terms of system parameters for determining acceptable system operations. The integrated maintenance procedures are intended to provide minimum preventive maintenance coverage of combat systems. The procedures are written to establish specific controlled conditions that challenge the fictions under test. In some cases, test efficiency and format restrictions make it difficult to determine the intent of a test from its procedural steps; therefore, the procedural sequences must be followed explicitly. Improvising or shortcutting procedural sequences often leads to incorrect troubleshooting or masking of actual faults.

The integrated maintenance concept is consistent with the PMS efforts, and it is the most effective means of achieving the goals of the PMS. Adhering to this concept enables maintenance managers to manage the combat systems maintenance effort and to achieve an optimum level of readiness with the most effective use of available personnel.

With combat systems testing being conducted at three levels, it is imperative that integrated maintenance tests be scheduled to reduce test redundancy whenever possible. The three levels of tests are combat systems testing, subsystems testing, and equipment testing.

Combat Systems Testing

Combat systems testing, defined as *testing that exercises a combat system as one entity,* is the highest level of testing that can be accomplished aboard ship. Combat systems tests are usually automated and are conducted and monitored from the ship's command and control center.

The overall combat system operability test (OCSOT) is the primary combat systems test tool. The OCSOT gives a good overview of detection, display and tracking, designation, acquisition, repeat-back position, and some status-signal monitoring. Simulated targets are used in the OCSOT. Although the test is conducted as if the combat systems were operating normally, certain operating stations dedicated to support the test are lost for normal operational use.

Although the OCSOT provides an overview of systems performance, it does not test the fill capacity of a combat system or its subsystems operability. It is impractical from an instrumentation and manpower standpoint to test all functional test requirements at the combat systems level. Therefore, confidence in operability or material readiness is mainly dependent on integrated testing at the subsystem and equipment levels.

Subsystems Testing

Testing that exercises two or more pieces of equipment fictionally contained within the same subsystem is defined as *subsystems testing.* Subsystems testing tests a subsystem in a stand-alone operation; however, some functions are provided by other subsystems, which require integrated testing.

Subsystems tests are functionally grouped and mode oriented so that related functions can be challenged using the same setup, procedures, and stimuli. Where practical, subsystems tests use tactical indicators for measurement, leaving the requirement for special hookups and test equipment to equipment-level testing.

A major combat ship contains most, or all, of the following subsystems:

1. Search-radar subsystem

2. Command and control subsystem

3. Countermeasure subsystem

4. Gun/missile weapon subsystem

5. External communications subsystem

6. Navigation subsystem

Equipment Testing

Equipment testing is defined as *testing that is generally directed toward power levels, frequencies, servos, special features, and output functions.* The PMS may require special external stimulating equipment and special- or general-purpose test equipment for testing measurements.

FAULT ISOLATION

The objective of fault isolation is the systematic application of fault-isolation tools needed to isolate the exact unit or fictional interface responsible for a fault or degraded operation during testing or tactical operation. To diagnose and effect timely repair of faults within a fire-control system, you must fully understand fault-isolation concepts, the fault-isolation tools available to you, and the capabilities and limitations of those tools when applied to system fault isolation.

Although the primary entry into fault isolation is from test-detected faults, improper operating conditions can be observed during tactical operations, including operator awareness, data extraction and reduction, and on-line monitoring.

Fault isolation leads to corrective maintenance. After a fault has been isolated to a specific unit or interface, corrective action in the form of repair, replacement, and/or alignment must be taken. The corrective maintenance performed may or may not be required to return the system to an operable condition. There may have been more than one fault contributing to the out-of-tolerance condition that initiated the fault-isolation process. The possibility of faulty replacement parts and incorrect adjustment or alignment exists. Instead of solving the problem, corrective maintenance may have added to it. Therefore, it is mandatory that each corrective action be followed by verification.

Normally, verification is accomplished by recreating the test environment and rechallenging the function. Where alignments are concerned, the interdependent effect upon other elements of the combat systems must be considered in the verification process.

FAULT-ISOLATION TOOLS

During testing or operational use of a weapons system, faults can occur in the interface between subsystems, in the interface between equipments of a subsystem, or in the equipment itself. Rapid fault isolation requires decisive action in selecting and implementing the most appropriate fault-isolation tools. A fault-isolation tool has the following three characteristics:

1. It requires the least amount of time, equipment, or service.

2. It is easily implemented.

3. It conveys the maximum intelligence regarding the source of the fault.

Tools used in fault isolation cover a wide range of applications, including (but not limited to) combat systems tests, subsystems tests, on-line/off-line testing, and diagnostic testing programs.

This section briefly covers these items and gives examples of their use, where appropriate.

Combat Systems Tests

Combat systems tests are the highest level of tests that can be performed to verify the readiness or alignment of a combat system. The OCSOT is one of the major combat systems tests; it is designed to test a combat system as a single, fictional unit. Major faults in the subsystems usually show up during the OCSOT; often, this is the first indication of a problem in a particular subsystem. Keep in mind, however, that the OCSOT does not test the full operability of a combat system or its subsystems; it provides only an overview of systems performance.

Another important test is the combat systems alignment test, which is a programmed test tool designed to measure the relative beam alignment (or misalignment) between a reference sensor and a sensor under test. The measure of misalignment is accomplished by collecting the range, bearing, and elevation data from the reference and test sensors. Then the test sensor data is compared to the reference data, and the results are shown on a display console for analysis. The sensors that can be tested include the gun or missile fire-control radars and surface-or air-search radars. A hard-copy printout can be obtained to provide a record.

Subsystem Tests

Subsystem tests aid in fault isolation by testing specific functions within a subsystem to determine if they are generated correctly. In many cases, these tests check the transmission of data between the subsystem under test and associated subsystems. Computer programs are available that provide specific test capabilities suited to subsystem testing. An example of such a program is the Programmed Operational and Functional Appraisal (POFA). The POFA programs, for which the subsystem test is named, are non-resident programs that detect and isolate malfunctions by transmitting selectively configured and controlled data between a computer and a computer ancillary equipment interface.

A typical example of a subsystem test is the fire-control system (FCS) daily system operability test (DSOT). The DSOT assesses weapons system readiness in the normal mode of operation for an antiaircraft (AA) target from designation through acquisition, track, weapons control, simulated firing, and post-firing evaluation.

Test procedures are controlled by the test conductor, who calls out the step numbers in sequence. The personnel performing the steps in the various spaces inform the test conductor when the action or observation required by that step is completed. No response restrictions are placed on personnel, except where the steps are underlined in the procedure. In this case, instruction words are also underlined, indicating the quantity or indication upon which the request for the response is based. Steps not underlined, but containing underlined instructions, denote the response requested (Mark, Fired, etc.). Underlined step numbers denote those steps to be recorded for evaluation and scoring.

All responses should be given as soon as practical after the completion of the step, particularly in those areas of the test where the timing is important or when a sequence of events must commence immediately after a required action or observation. Timely responses aid in decreasing time requirements.

When a fault occurs during combat systems or subsystems testing and before detailed fault-isolation procedures are initiated, the operational steps should be repeated to ensure that the fault is an actual fault and not an operator error. If the fault still exists, you should ensure that the combat system or subsystem is properly configured for the test event performed; that is, switches are properly set, correct function codes are selected, etc.

On-Line/Off-Line Testing

Based on the level of testing selected, on-line maintenance testing can assist in fault isolation by testing suspected equipment or systems with a minimum of interference with normal ship operation. If a suspected equipment or system checks out satisfactorily, then a possible source of the fault has been eliminated. This aids in the fault-isolation process. In general, the use of on-line testing provides a quick fault-isolation tool when you are trying to confirm equipment or system problems. When using on-line testing, you should be careful not to degrade the system or subsystem operational capability beyond the level specified by ship doctrine.

Some combat systems equipment has the capability of severing normal communications links and accepting preset or manual inputs when you are verifying system ability to correctly process data. This off-line testing offers a convenient method of isolating equipment or interface faults. As in on-line testing, care must be taken not to degrade the system or subsystem operational capabilities. One such off-line test is the system maintenance test (SMT) used in the Mk 86 gunfire control system (GFCS).

The SMP is a computer program that enhances fictional testing and troubleshooting of the FCS. The SMP provides test conditions to check the integrity of input/output circuits to and from the computer and to check the fictional integrity of various functional systems. It is loaded into the FCS computer in place of the normal (tactical) FCS operational program. Therefore, the FCS is not functional in a tactical sense until the FCS operational computer program has been reloaded into the FCS computer following the use of the SMP.

The program includes a configuration entry routine, an executive routine, and approximately 60 individual tests that are organized into groups according to the interface channels between the computer and the peripheral units. Configuration entry allows the technician to adapt the program to a particular modification of the FCS. The executive routine provides the basic timing requirements for each test program and establishes testing priority in the event two or more tests are selected concurrently.

The tests are grouped according to channel and unit numbers as follows:

- Channel 14 test programs are selected from units 1, 2, and 3.
- Channel 15 test programs are selected from unit 25.
- Channel 16 test programs are selected from unit 22.
- Channel 17 test programs are selected from unit 6.

A sample of channel 14 test programs is shown in table 1-1. Notice that the tests selected at unit 2 or 3 are selected with a test number select code. The procedures for setting up these codes are in table 1-2.

Table 1-1.—System Maintenance Program Channel 14 Test Programs

UNIT 2, 3 TEST NUMBER SELECT CODE	TEST SELECTED
00000	Initial data display
00001	Address decode test
00002	NIXIE cycle test
00003	WCC keyboard test
00007	Mode sequence indicators test
00009	WCC projectors test
00010	Inputs test 10
00011	Inputs test 11
00020	RAM test
00021	Symbol decoder test
00022	Screen test
00040	B-scan test — standard
00041	—reduced
00042	—X standard
00043	—X reduced
00044	—Y standard
00045	—Y reduced
00050	Gun data test
00060	Servo test —(gain = 16)
00061	—(gain = 8)
00062	—(gain = 4)
00070	Encoder test
00080	Gun align display
00180	Memory call-up test — random
000181	Memory call-up test — consecutive
UNIT 1 DESIGNATOR SELECT SWITCH	**TEST SELECTED**
ROS	COC select 1 and 2 input words
NTDS	COC TDS input words
TARTAR	COC select 2 and COC/CWI or
SPA	WCS input words
TDT1	COC control input words
TDT2	SRM trackball
TDT3	PPI test
TDT4	PPI (X) test
SPQ9	PPI (Y) test
SEARCH	Marker test
IDD	B-scan range gate test
	PPI range gate test

Table 1-2.—Procedures for Setting Up Test Number Select Codes

STEP	PROCEDURE
1	At the matrix selector (group of six switches) on unit 2 or 3, press the TEST pushbutton to light the legend green. (This causes the test matrix to appear. See figure 1-2.)
2	Press the TEST NO SEL pushbutton (located on the first column of the first row of the matrix) to light its legend green.
3	At the keyboard, press CLEAR, type in the test number select code, and press ENTER. (The selected test will begin running. It is not necessary to type in leading zeroes. For example, if the test code is given as 00011, it is only necessary to type in 11.)
4	To terminate the test, press CLEAR and ENTER. (This effectively enters test select code 00000, which terminates the test and calls back the initial data display.)

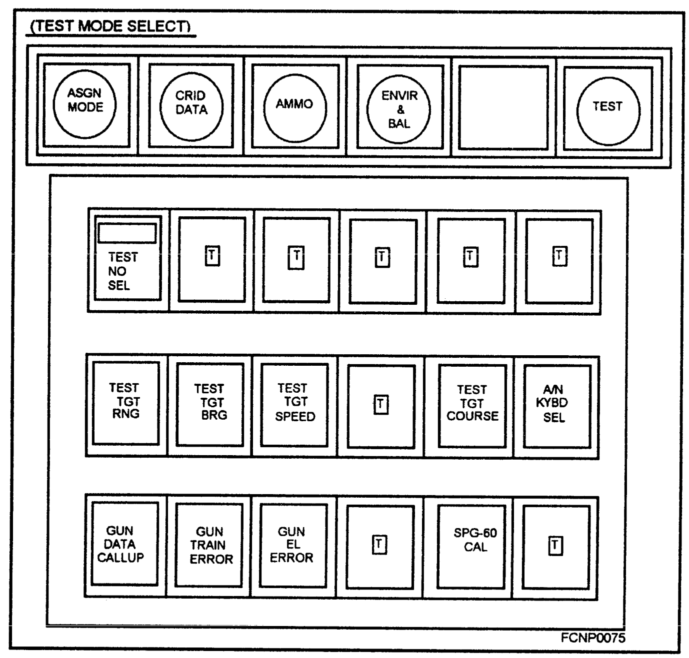

Figure 1-2.—Sample test mode matrix.

Since it is not practicable to list all the possible tests in the SMP, this discussion is limited only to channel 14 test programs. The channel 14 test programs consist of a scan generator test routine and various test routines that can be selected from unit 1, 2, or 3. Test routines are selected from unit 2 or 3 by using test number select keyboard code entries to the computer.

The DESIGNATOR SELECT switch positions at unit 1 select tests from unit 1. Table 1-1 lists units 2 and 3 test number select codes and unit 1 DESIGNATOR SELECT switch positions used to select the test routines.

The following paragraphs provide a synopsis of selected channel 14 test programs:

- **INITIAL DATA DISPLAY:** This test provides an initial data display to the A/N display for entering initial test data required for the channel 17 end-around, D/A converter, gun data, and encoder tests.

- **ADDRESS DECODE TEST:** This test outputs a unique number to each unit (1, 2, or 3) readout to verify proper address encoding and console address decoding.

- **NIXIE CYCLE TEST:** This test cycles all of units 1, 2, and 3 NIXIE readout digits from O to 9, in unison, in a 10-second period. The test checks the channel 14 output lines and the readout digital logic.

- **GUN DATA TEST:** This testis similar to the channel 17 end-around test, except that the test results are displayed on the A/N display, rather than on a printout. The test should be used for fault localization, rather than for fault detection.

- **SERVO TESTS:** These tests check out the stiff-stick data, the camera-assigned codes, and the TV sight 1 and sight 2 servo systems. The servo systems can be checked using a servo gain of 8, 4, or 2.

- **MEMORY CALL-UP TESTS:** These tests are used to monitor up to 12 randomly selected or consecutive computer memory locations and to display them on the A/N displays.

When the technician troubleshoots with the aid of the SMP, it is sometimes useful to know what data the computer is transmitting and receiving. The memory locations of all active computer input and output buffers can be called up by using this routine.

Diagnostic Testing Programs

Diagnostic testing programs are designed to isolate malfunctions that occur in the internal logic of the printed circuit boards. When other types of failures occur, manual procedures are required, but, in many cases, the diagnostics provide sufficient information to identify the fictional area of the failure.

Diagnostic testing programs are useful in locating a problem in a piece of equipment once the problem is isolated to a unit. The unit can be systematically tested with a printout or readout provided to the technician to indicate the problem area. Some diagnostic programs provide an error-code readout, whereas others provide the direct location of suspected faulty components.

An error-code readout requires searching an area-code table to locate the possible bad component, while the direct component-location readout tells the technician where the problem could be located. The direct component-location readout method is usually faster in producing the location of suspected failed components.

MAINTENANCE SUPPORT DOCUMENTATION

Maintenance support documentation falls into two general categories: (1) logic diagrams that contain a sequence of steps to isolate the faults causing a specific test- or operation-related fault symptom, and (2) system or equipment functional flow diagrams that allow the technician to determine a sequence of isolation steps.

1. LOGIC DIAGRAMS: Logic diagrams include troubleshooting logic charts (TLCs), fault logic diagrams (FLDs), fault isolation pyramid charts, and fault reference tables. The TLCs and the FLDs provide a simple yes-or-no, question-and-answer approach to fault isolation. They are generally based on either a ladder method or a bracket-and-halving fault-isolation technique.

- **Ladder Method:** The function is approached from its initiation or termination point and, in successive steps, is checked to the other end.

- **Bracket-and-Halving Fault-Isolation Technique:** The function is checked at its midpoint, then at the midpoint of the half containing the fault, etc., until it is isolated.

Pyramid charts take an output or terminal function (output, indicator, etc.) and break it down into its major subfunctions, which are individually checked until the fault is isolated. Fault reference charts generally relate symptoms to specific faults.

2. FUNCTIONAL FLOW DIAGRAMS: Functional flow diagrams include system functional diagrams, signal-flow diagrams, schematic diagrams, and relay-ladder diagrams. These are frequently used in isolating a fault that was not anticipated by the fault logic material provided.

In general, fault logic procedures are used more rapidly by inexperienced technicians than fictional diagrams in isolating a specific fault. When used with flow diagrams, fault logic procedures provide a means of teaching new or inexperienced personnel effective fault-isolation techniques. A fictional understanding gained through the use of maintenance documents is necessary for the development of experienced technicians. Experienced technicians frequently isolate specific faults addressed in fault logic procedures faster without referring to procedures. Their experience is essential in isolating problems that have not been anticipated by logic procedures.

Numerous approaches are possible in the application of fault-isolation procedures. The fact that most casualties occur within an equipment and are corrected by troubleshooting on an equipment-level basis leads to the tendency to troubleshoot all casualties on an equipment-level basis. It is to be expected that each technician might rely more heavily on certain troubleshooting aids and procedures than others. Few hard-and-fast rules apply to all troubleshooting situations, but one rule that should always be foremost is to determine the origin of a fault as precisely as possible.

System interrelationship is such that many casualties can be reflected in several areas as improper operation or fault indications. If each area of each equipment that does not function properly is checked separately, the equipment downtime and corresponding man-hour use can rapidly increase. On the other hand, familiarity with system reference materials, system fictional diagrams, and fault-isolation procedures can lead logically and expeditiously to the specific area of the fault.

All system fault isolation is interrelated. Its effective use depends on knowing what materials are available, how they are interrelated, and how to cross--reference between materials. The isolation materials that you will use in fault isolation are the system fault indicator director, the system function directory, the system functional diagram, the fault analysis matrix, a sample troubleshooting problem, and the equipment troubleshooting documentation.

System Fault Indicator Directory

The system fault indicator directory (FID) facilitates entry into the documentation required for troubleshooting a fault disclosed by a specific indicator during normal operation. A typical FID is shown in table 1-3. The material in this FID is grouped by system and further divided alphabetically by equipment, panel, and indicator. A complete listing of indicators is included.

Table 1-3.—Typical Fault Indicator Directory

EQUIPMENT	INDICATOR	INDICATOR TYPE	SPD FIGURE REFERENCE & SHEET NO.	SMT/FAM REFERENCE
FCS SPC-XX RDP	PS1 MULTIVOLT PS2 +5V SC ON	LAMP LAMP LAMP	12-13.1 (3) 12-13.1 (3) 12-13.1 (3)	
RSC 21A1	CWI GROUP EMCON/RADHAZ	LAMP	12-11.5	
	FCS ECM ALERT GROUP COHERENT ECM RESET NOISE ECM NOISE REPEAT			
	RDP GROUP ON/OFF TEST/READY	LAMP	12-11.2	W-1, Table 10-2.1 W-1, Table 10-2.1
	SYSTEM STATUS GROUP CONTROL ALARM GO PERMISSION TO TEST RDP FAULT	LAMP LAMP LAMP LAMP	12-11.2 12-13.1 (3) 12-14.1 (1) 12-13.1 (3)	W-1, Table 10-2.1
	TRACK GROUP EMCON/RADHAZ	LAMP	12-11.5	

The reference provided for each indicator includes a system functional diagram (SFD) and an applicable fault analysis matrix (FAM) reference. The SFD reference pertains to the SFD figure used to troubleshoot the fault on the system level, which the individual indicator indicates. The applicable FAM reference is used for troubleshooting and for verifying the operational status of the system on an equipment level.

System Function Directory

The system function directory is used with the FID. It contains an alphabetical listing of all system fictions contained in the SFDs. This directory can be used to start the troubleshooting process when there is no particular indicator associated with a fault. A sample fire-control system function directory is shown in table 1-4.

Table 1-4.—Sample Fire-Control System Function Directory

FUNCTION NAME	SYMBOL	ORIGIN/TERMINATION	APPROPRIATE VERIFYING TEST	SFD FIGURE NO.	DESCRIPTION PARTS 030 SECTION NO.
Noncoherent Video		FM: RDP TO: RSC		12-7.2 (2)	
Normal Track		FM: RDP		12-8.1 (1)(2)	
Ownship Heading	Cqo	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Ownship Pitch	Eio	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Ownship Roll	Zdo	FM: CS SWBD TO: RDP VIA: PDS		12-5.2 (4)	
Permission to Test		FM: C152 TO: RSC RTS VIA: SDC RDP		12-14.1 (1)	
Passive Track		FM: RDP		12-8.1 (2)	
Preheat Indicator		FM: CWI XMTR		12-11.1 (3)	
Pretrigger		FM: RDP TO: RFTTG		12-14.1 (1)(3)	
Pulse Radiate Command		FM: RDP TO: PULSE XMTR/ RCVR VIA: RSC PULSE PS TO: RTS VIA: RSC		12-11.6 (1)(2)	
Query Command		FM: ADP TO: RDP		12-13.1 (4)	
Radar Elevation Error		FM: RDP TO: RSC		12-7.2 (2)	
Radar Evaluation GO/NO-GO		FM: RDP TO: RTS VIA: RSC		12-14.3	
RF Power		FM: XTMR/RCVR TO: ANT		12-7.1 (4)	
Radar Traverse Error		FM: RDP TO: RSC		12-7.2 (2)	
RADHAZ		FM: CONT 178 TO: PULSE PS CWI XMTR VIA: RSC		12-11.5	
RADHAZ Supply		FM: PDS TO: CONT 178		12-16.1 (1)	
Radiate Indicate		FM: CWSI XMTR TO: CONT PS		12-11.1 (3)	

System Functional Diagram

A system fictional diagram (SFD) contains all primary and secondary circuits necessary for an understanding of the function of a particular mode, loop, or phase of system operation. Each function is shown from source to termination. Data flow is normally from left to right. All serial components of each piece of equipment in the loop that are significant to functional understanding are shown. All readout devices, test points, etc., in each equipment that are significant to system troubleshooting are included on the SFD. A sample weapons system fictional diagram is shown in figure 1-3.

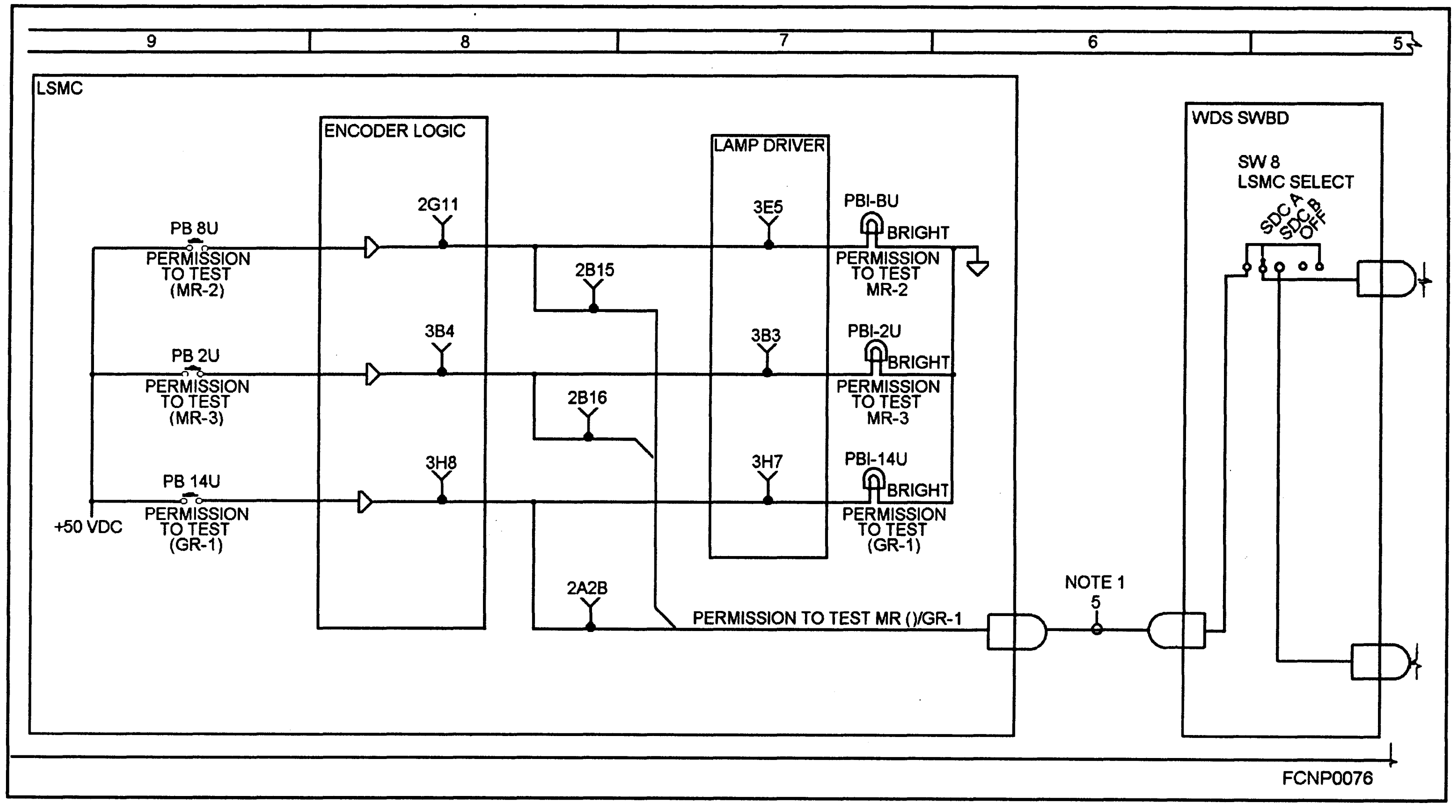

Figure 1-3.—Sample weapons system functional diagram.

Fault Analysis Matrix

The fault analysis matrixes (FAMs) and their associated troubleshooting procedures are related to each other and to the SMTs. Together, they provide maintenance personnel with an effective troubleshooting package.

To keep this material as specific as possible, the following assumptions are made:

- All equipment has been properly energized and indicator lamps have been tested.
- Associated switchboards are setup correctly, all power lamps are lit, and no fuses are blown.
- Troubleshooting faults do not begin until the test is completed, if possible. This procedure allows the technician to troubleshoot several related faults simultaneously, reducing troubleshooting time.
- Troubleshooting faults should occur in the same sequence in which the faults are discovered; for example, a fault discovered in step 9 of an SMT should be corrected before a fault discovered in step 14. Adherence to this sequence for correcting faults is

desirable because the initial fault observed during a test may be the cause of those observed thereafter. Thus, correcting the initial fault may correct those observed later in the test sequence.

The FAM is arranged in tabular form to provide a quick cross-reference of troubleshooting aids and reference materials. Table 1-5 is a sample fault analysis matrix.

Table 1-5.—Sample Fault Analysis Matrix

1	2	3	4	5	6	7
STEP	**FUNCTION**	**SOURCE[*]**	**INTERMEDIATE UNIT[‡]**	**RELATED SMT[◊]**	**REFERENCE**	**SUGGESTED FAULT-ISOLATION PROCEDURE[°]**
1a	Restore/Delete MR-( )	FCSC	TDS C&C SWBD C152	W-2	Fig. 11-22.5	Perform WDS CMPTR diagnostics.
1b	MR-( ) AVAIL	FCSC	TDS C&C SWBD	W-2	Fig. 11.21-6	Perform WDS CMPTR diagnostics.
2	MR-( ) Go	C152	SDC WDS D SBD LSMC	W-2	Fig. 11-13.3	Perform WDS CMPTR diagnostics.
3	Ownship Display a. M at Ownship b. Ownship Heading c. Launcher Blind Zone d. MR-( ) Symbol	C152	WDS D SWBD		Fig. 11-24.1	Perform WDS CMPTR diagnostics.
4	Permission to Test	LSMC	WDS CS SWBD SDC C152 RDP	W-2	Fig. 12-14.1	a. Perform C-TASC IM/CB Test 877 b. Perform continuity check between RDP (J11-c) and RSC (J4-c). c. Perform ground check at RSC (J4-c) and P4-c). d. Perform SDC signal monitoring and fault monitoring (SM/FM) tests.

[*] This column lists the function source and test points, if applicable.

[‡] This column lists units between source and destination.

[◊] This column lists other SMTs and associated steps in which the parameter in the function column is tested, if applicable.

[°] This column provides suggested troubleshooting procedures for fault isolation; for example, applicable self-tests, alternate system configuration/substitution, etc. It should be emphasized that these are suggested troubleshooting procedures and are not meant to preclude or remove judgment for troubleshooting from the technician. The intent of the FAM is to serve as a troubleshooting aid, while allowing latitude for personal preference as to the approach and technique applied.

Sample Troubleshooting Problem

To show how troubleshooting documentation is used to isolate faults, this sample problem is provided with corresponding fault analysis procedures by using samples of fault-isolation materials previously covered in this chapter. The sample problem and associated fault analysis procedures are based on a fault revealed during SMT W-1. It is emphasized that these are *suggested* troubleshooting procedures and are not meant to preclude or remove judgment from the technician. For the sake of clarity, this problem is shown as separate steps. Refer to table 1-5 as you solve this problem.

1. Prior to the hypothetical fault, it is assumed that all turn-on procedures and preliminary test steps have been accomplished with no apparent malfunctions indicated. No PERMISSION TO TEST indication is observed at the radar set console (RSC).

2. After verification of all test setups, the test coordinator then refers to the FAM for SMT W-1, which lists all SMT response steps (column 1) and the associated functions that are tested (column 2).

3. From columns 3 and 4, the sources and intermediate units can readily be determined.

4. Column 5 lists related SMTs.

5. Column 6 lists SFD figure 12-14.1 as the reference for the permission to test the function. By using the available reference material, the test coordinator can proceed to column 7 and implement the suggested fault-isolation procedures.

6. In column 7, step 4a, C-TASC (a computer diagnostic program) is used to determine if logical output voltages are being (1) generated at the radar data processor (RDP), and (2) transmitted to the radar set console (RSC). The succeeding fault-isolation procedures listed in the FAM are then accomplished as required until the casualty is found or isolated to an equipment.

If the preceding problem had arisen at any time other than during a scheduled test, the system FID (see table 1-3) and/or the FCS function directory (see table 1-4) could have been used.

When the FID is used to facilitate solutions of problems encountered during normal operations or weapons system exercises other than scheduled testing, the faulty indication is identified and located in the Indicator column for the associated equipment listed in the Equipment column of table 1-3. Using the same hypothetical fault described above, refer to table 1-3 and locate the RSC in the Equipment column and PERMISSION TO TEST in the Indicator column. The applicable SFD and FAM may then be refereed to for trouble analysis. At the discretion of the test coordinator, the equipment may be setup as required in the referenced FAM, and the associated trouble analysis procedures accomplished as described in the above paragraphs. Where there is no readily identifiable indicator for a given function, reference maybe made to the SFD to cross-reference the applicable SFD.

Equipment Troubleshooting Documentation

Equipment operating procedures (OPs) contain a wealth of documentation to enable the rapid localization of faults that have been traced to a particular piece of equipment. The documentation includes (but is not limited to) fault logic diagrams, signal-flow diagrams, pyramid diagrams, relay and lamp indexes, and relay lamp ladder diagrams. In addition, maintenance turn-on procedures, shown in table 1-6, are provided for energizing the equipment. These procedures contain references to troubleshooting documents that are to be used if a given step of the procedure cannot be performed satisfactorily.

Table 1-6.—Sample Maintenance Turn-On Procedures

STEP	PROCEDURE	OBSERVATION	REFERENCE
1	Perform preliminary preparations in accordance with paragraph 2-17.		
2	At Control-Power Supply, perform the following: a. Press OFF-ON push button switch 14A2S5.	ON is lit.	4-5
	b. Observe PREHEAT indicator of PREHEAT switch 14A2S8.	PREHEAT is lit.	4-5
	c. Press COMMAND STANDBY pushbutton switch 14A2S9.	COMMAND is lit. STANDBY is lit after approximately 5 minutes.	4-5 4-5
	d. Observe LOW VOLTAGE lamp 14A2DS2.	Lamp is lit.	4-6

Some of the primary equipment troubleshooting documentations are covered in this subsection, including fault logic diagrams, signal-flow diagrams, pyramid diagrams, relay and lamp indexes, and relay lamp ladder diagrams. Also included is a sample equipment troubleshooting problem relating to a simple checkout procedure.

FAULT LOGIC DIAGRAMS.— Fault logic diagrams (FLDs) are used to speed troubleshooting by requiring the technician to answer a branching series of questions about an observed system fault. The questions, which permit only yes-or-no answers, pertain primarily to the status of external indications (lamps, dials, meters, scope displays, etc.), but they may also include internal indications at key test points. By a process of elimination, the technician is led to the area of probable trouble and is referred to equipment troubleshooting documents. Figure 1-4 shows a sample fault logic diagram.

SIGNAL-FLOW DIAGRAMS.— Signal-flow diagrams show the signal flow from an input to an output function. Adjustment procedures, replacement procedures, and schematics are referenced in the signal-flow diagram to provide the technician with quick access to the appropriate maintenance requirement cards and related troubleshooting documentation. Figure 1-5 shows a sample signal-flow diagram.

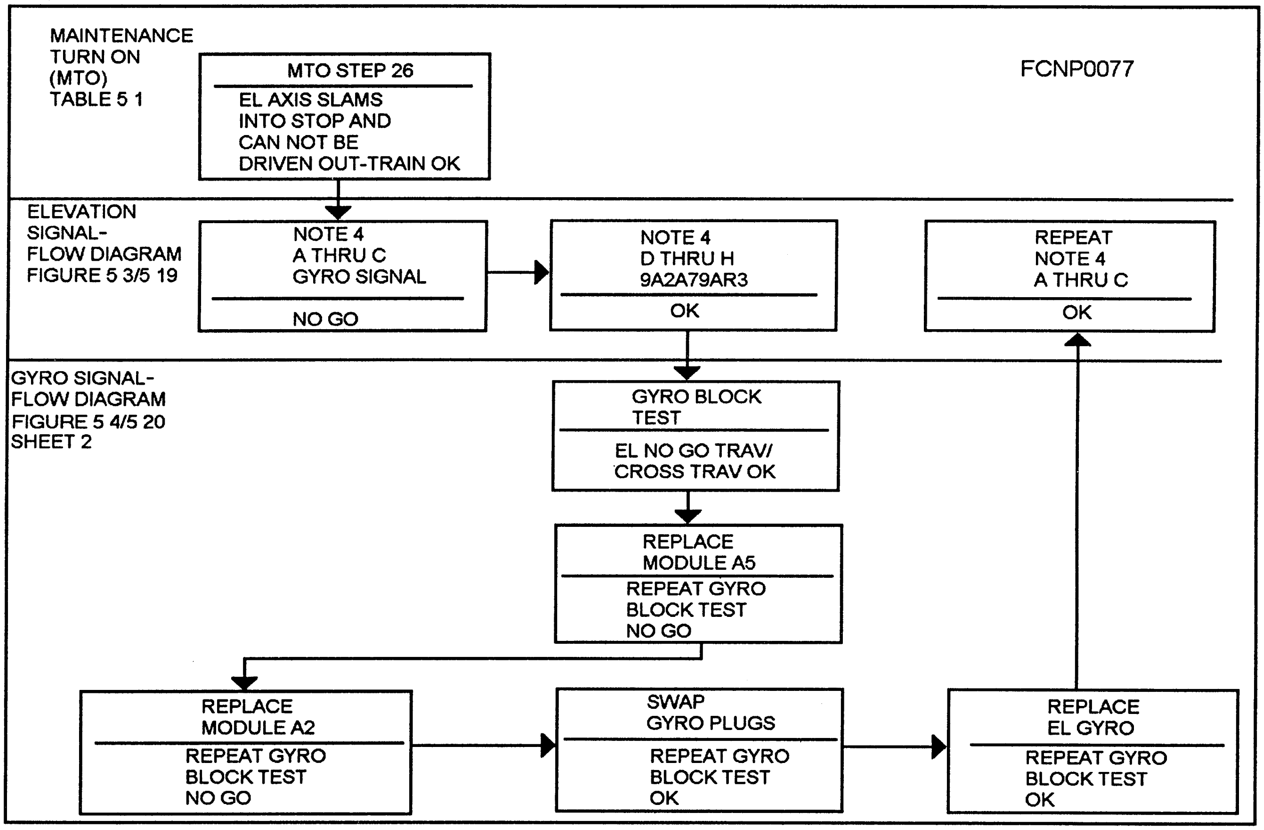

Figure 1-4.—Fault logic diagram.

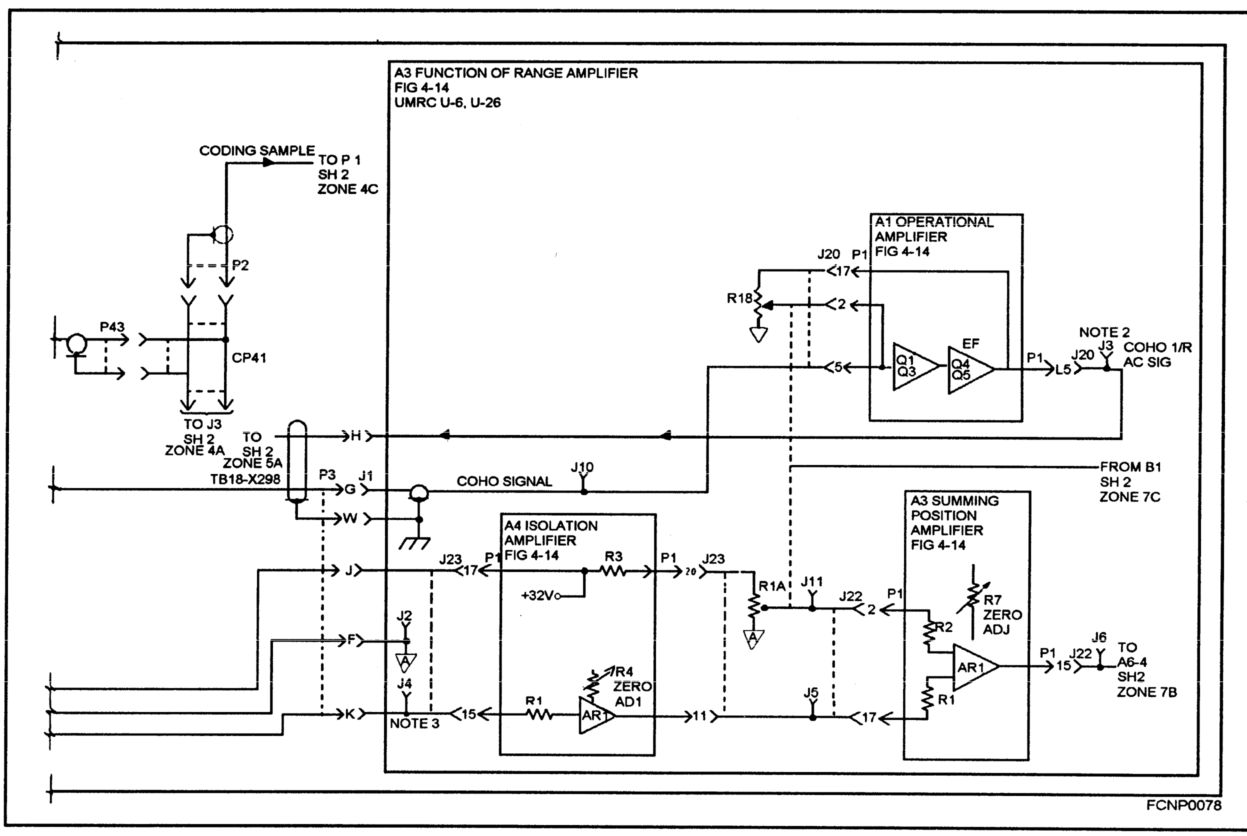

Figure 1-5.—Signal-flow diagram.

PYRAMID DIAGRAMS.— Pyramid diagrams pertain to the interdependency of the subassemblies essential to each function of a piece of equipment. The pyramid starts with an output function and, for a given local test setup, lists the values and allowable tolerances of that function. Subsequent checks of the various inputs that affect the function are contained in blocks, which radiate downward from the statement of the function.

The blocks contain recommended corrective action if the check of the input is at fault. Each leg of the pyramid is terminated by an input and a reference to other pyramids or related documents. Thus, the equipment troubleshooting pyramids should enable the technician to quickly localize faults and perform the necessary corrective action by referencing the associated material. Figure 1-6 shows a sample pyramid diagram.

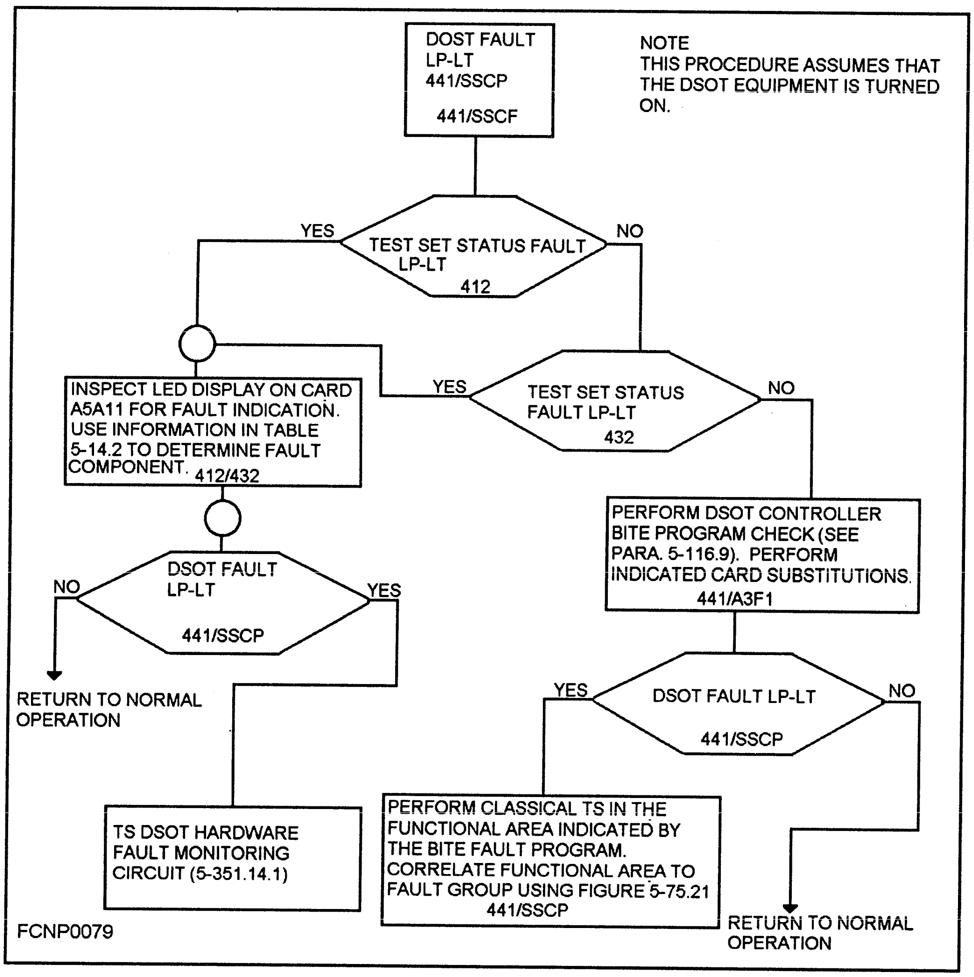

Figure 1-6.—Pyramid diagram.

RELAY AND LAMP INDEXES.— The relay and lamp indexes list all the relays and lamps shown on the troubleshooting diagrams. The indexes list, in unit designation sequence, all relay coils and related switches and indicator lamps. They cross-index (by figure, sheet, and zone) the location of the relay coil and indicator lamp energizing paths. Table 1-7 shows a sample relay index.

Table 1-7.—Sample Relay Index

RELAY	FUNCTION	COIL SUPPLY	FIGURE MOD 5	FIGURE MOD 6	SHEET	ZONE	CONTACT LOCATION FIGURE MOD 5	CONTACT LOCATION FIGURE MOD 6	CONTACT LOCATION SHEET	CONTACT LOCATION ZONE
9A4K2	Missile in Flight (KMIF)	50 V dc	5-8	5-24	1	B6	5-9 5-6 5-7 5-8	5-25 5-22 5-23 5-24	1 1 1 1	C7 C1 A5 B5
9A4K3	Electronics Unplugged Interlock (KEUI)	50 V dc	5-7	5-23	2	A2	5-7 5-7	5-23 5-23	2 1	A1 A1
9A4K4	Electronic Voltage Supply (KEVS)	50 V dc	5-7	5-23	2	A2	5-9 5-7 5-7	5-25 5-23 5-23	1 2 1	C7 A1 A1
9A4K5	Director Running (KDR)	50 V dc	5-8	5-24	1	B4	5-8 5-9	5-24 5-25	1 1	B1, B2 C7
9A4K6	Director Test (KDT)	50 V dc	5-8	5-24	1	B6	5-8 5-10	5-24 5-26	1 1	B2, B3 C9
9A4K7	Train Overspeed (KTOS)	50 V dc	5-6	5-22	2	A4	5-9 5-9	5-25 5-22	1 2	B8 A4, B1, B3
9A4K8	Elevation Overspeed (KEOS)	50 V dc	5-6	5-22	2	A4	5-9 5-6 5-6	5-25 5-22 5-22	1 1 2	B8 B2 A4, B1, B2
9A4K9	Train Overspeed (KTOS)	50 V dc	5-6	5-22	2	A4	5-6 5-6	5-22 5-22	2 1	A6 B2, B3
9A4K10	Power Amplifier Test (KPAT)	50 V dc	5-10	5-26	1	C9	5-11	5-27	1	C7
9A4K11	Train Control (KTC)	115 V dc	5-9	5-25	1	B8	5-9 5-11	5-25 5-27	1 1	A5, B9 C8

RELAY LAMP LADDER DIAGRAMS.— Relay lamp ladder diagrams show the energizing paths for relays and indicator lamps that are not covered by signal-flow diagrams. They are used with relay and lamp indexes. Figure 1-7 shows a sample relay lamp ladder diagram.

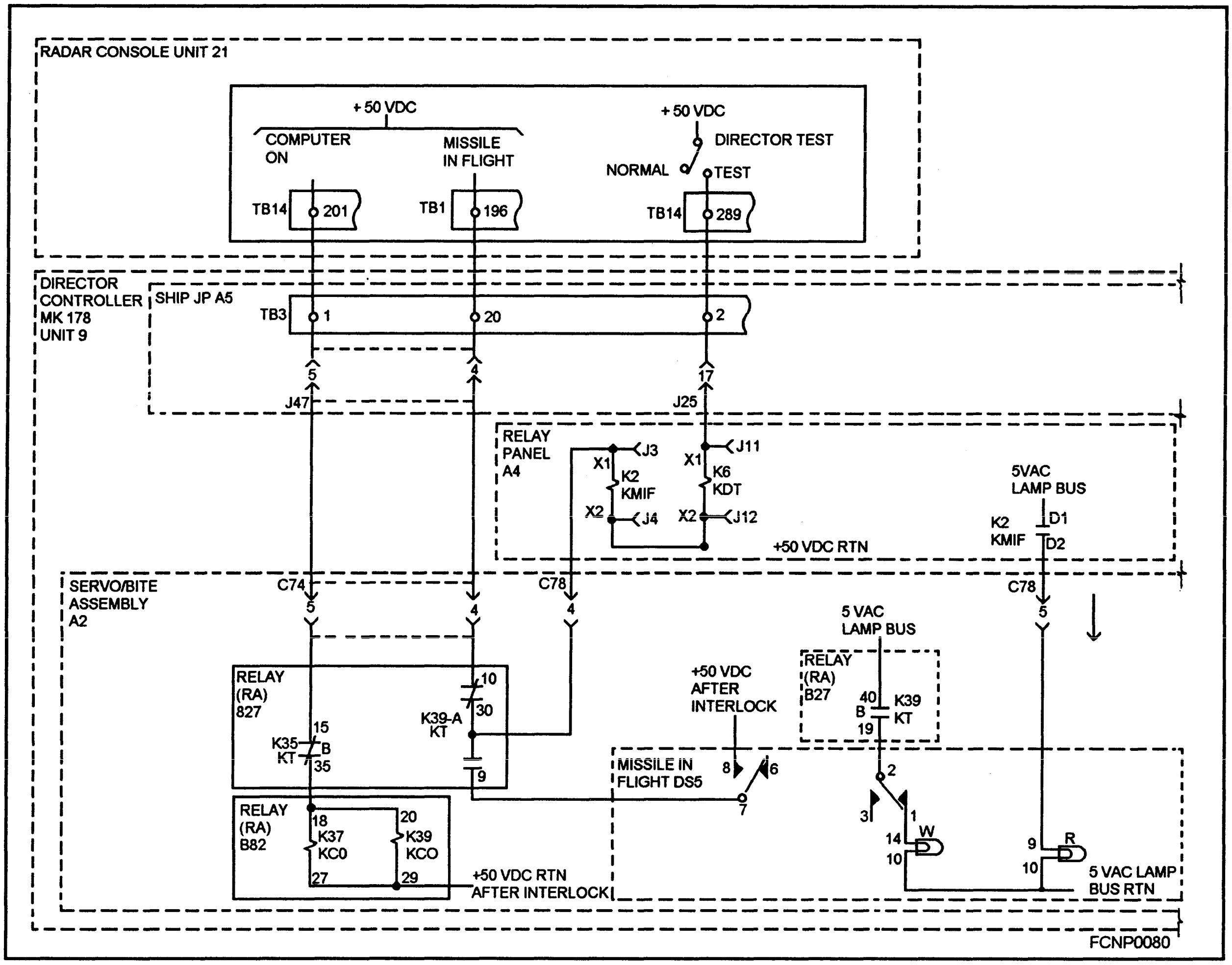

Figure 1-7.—Relay lamp ladder diagram.

The relay lamp ladder diagram is a troubleshooting support document for the signal-flow diagram and the maintenance turn-on procedure. It is also used as the prime troubleshooting document for equipment switching problems.

The relay lamp ladder diagram traces the energizing path for the relay coil or indicator lamp from a common interface point appearing on both the power-distribution diagram and the ladder diagram. It traces through the equipment, to the respective relay coil or indicator lamp, and to a common return power interface. The relay lamp ladder diagram shows cabling, terminal connections, relay contacts, switches, and lamps in the energizing path.

SAMPLE EQUIPMENT TROUBLESHOOTING PROBLEM.— Because of the inherent differences in fire-control equipment, each fire-control system has its own troubleshooting philosophy. However, they all use the basic troubleshooting documentation (or a modification or combination of the basic documentation) covered in this chapter.

This sample problem uses the checkout procedure, and the problem-directory and pyramid-diagram methods of troubleshooting. In these methods, the technician sets up, adjusts, and verifies equipment operation according to a set of steps in the checkout procedures shown in table 1-8.

If the function being tested at a particular step fails, the technician refers to that same numbered step in the problem directory to isolate the faulty component. A sample problem directory is shown in table 1-9.

Table 1-8.—Sample Video Processing and Distribution System Checkout Procedures

STEP	PROCEDURE
1	Set up radar video processing and distribution system troubleshooting initial conditions according to paragraph 7-13-8.
2	At unit 1, set SWEEP RANGE (NMI) switch to 5.
3	Adjust VIDEO GAIN and INTENSITY for optimum video and sweep presentation.
	•
	•
27	Set M/N SELECT switch to 10, and verify that all lamps on 25A38 are lit.
28	Set M/N SELECT switch to 4, and verify that all lamps on 25A38 are out.
29	Set M/N SELECT switch to 5, and verify that all lamps on 25A38 are out.
	•
	•

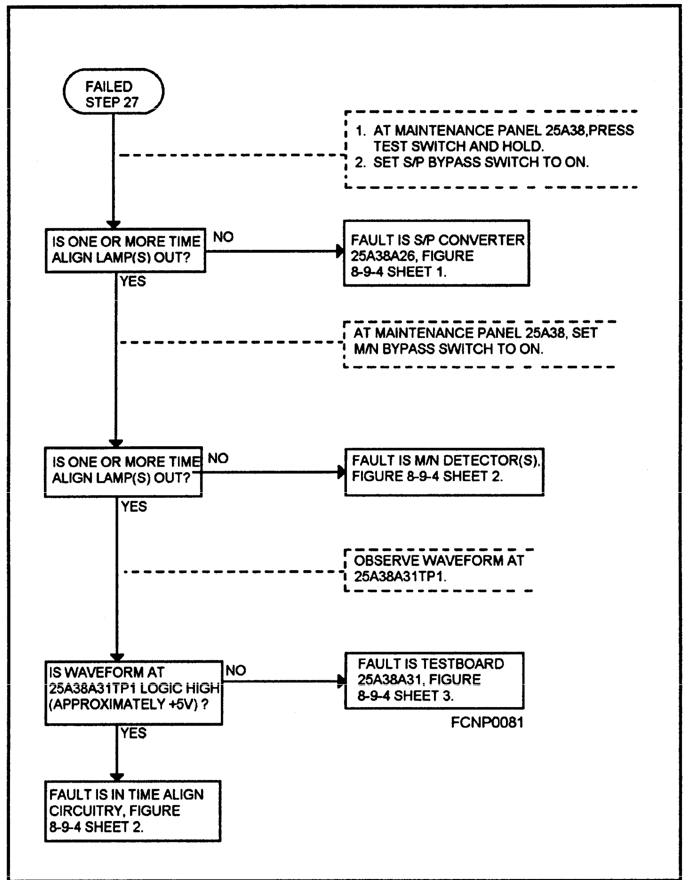

Figure 1-8.—Incorrect lamp pyramid diagram 7-13-2.

In our sample troubleshooting problem, the faulty component is Test Board 25A38A31. To isolate this component, the technician performs the checkout procedures shown in table 1-8. At step 27, the technician observes that none of the lamps on 25A38 are lit. From here, the technician proceeds to the problem directory (see table 1-9), step 27, where he is directed to set the S/P BYPASS switch to ON. After doing this, he notices that more than one lamp is out on 25A38. The problem directory refers the technician to the incorrect lamp indicator pyramid diagram, shown in figure 1-8.

Here, the technician follows the instructions outlined in the dashed blocks and answers the questions in the solid block. Eventually, the technician is instructed to measure the voltage at 25A38A3lTPI. A zero-voltage reading at this test point indicates that Test Board 25A38A31 is the faulty component. The technician replaces the circuit board and verifies correct operation by repeating step 27 in the checkout procedures.

Figure 1-9 is a sample troubleshooting system fictional diagram.

Table 1-9.—Sample Problem Directory

FAILED CHECKOUT PROCEDURE STEP	INDICATION	PROCEDURE
3	Adjusting VIDEO GAIN and INTENSITY controls does not provide optimum video and sweep presentation.	Refer to the PPI display system troubleshooting, section 7-15.
4	Type 1 synthetic raw video is not present or is not well-defined.	Refer to figure 7-13-1.
5	ACQUIRE 1 does not light green.	Refer to operator-to-computer buffer system trouble-shooting, section 7-5.
•	•	•
•	•	•
27	All lamps on 25A38 out.	Set S/P BYPASS switch to ON. If lamps light, fault is in S/P Converter 25A38A26, figure 8-9-4, sheet 1. If lamps stay out, fault is in MN/SELECT Switch 25A38S5 or Test Board 25A38A31, figure 8-9-4, sheet 3.
	One or more lamps on 25A38 out.	Refer to figure 7-13-3.
	CLR PLOT VID lamp out.	Fault is in P/S Converter 25A38A27 or Test Board 25A38A31, figure 8-9-4, sheet 3.
•	•	•
•	•	•

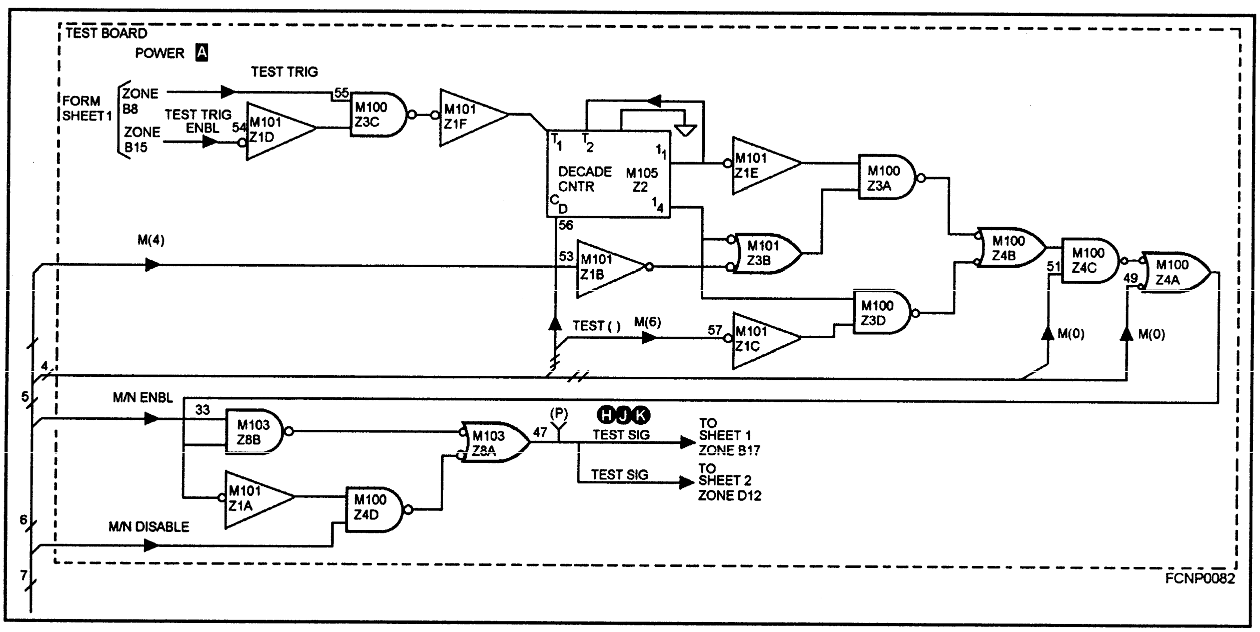

Figure 1-9.—Troubleshooting system functional diagram.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Ships' Maintenance and Material Management (3-M) Manual, OPNAVINST 4790.4, Chief of Naval Operations, Washington, DC, 1994.

All systems operating procedures that describe troubleshooting techniques and procedures applicable to each FCS on your ship class.